

**PROCESS FOR THE PRODUCTION OF A ROTOR,
CONTAINING PERMANENT MAGNETS, OF A SYNCHRONOUS
MACHINE, AND ROTOR PRODUCED ACCORDING TO THIS PROCESS**

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. § 119 to German Patent Application No. 100 60 121.9 filed on December 4, 2000, the entire contents of which are incorporated by reference herein. In addition, this application is a divisional application of U.S. Patent Application Serial No.09/996,694 filed on November 30, 2001, the entire contents of which are incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention relates to the production of a rotor, containing permanent magnets, of a synchronous machine, which rotor has a core of ferromagnetic steel, on which and connected to the core of which are permanent magnets which in turn are surrounded by an outer cylinder of a non-magnetizable steel, and which rotor has closure plates of a non-magnetizable steel with a stub shaft.

BACKGROUND OF THE INVENTION

[0003] In the operation of a permanent magnet excited synchronous machine, the permanent magnets seated on the rotor are exposed to considerable centrifugal forces, with the consequence that they tend to come loose from the rotor. Shrinking on a metallic cylinder over the magnets seated on the rotor is known. The permanent magnets, as is well known, consist of a brittle material, so that cracks and breaks are already practically unavoidable when shrinking the cylinder on. These permanent magnets moreover consist of a material which is very susceptible to corrosion and have to be wholly surrounded by a protective layer which is also durable during operation. The application of such protective layers on the one hand requires much work and on the other hand, in known constitutions, leaves broken places on the permanent magnets, occurring on (a first) run-up to operating rotational speed, without any protection against corrosion. It is known that the permanent

magnets have to be ground to obtain correct dimensions, This grinding also requires much work.

SUMMARY OF THE INVENTION

[0004] The invention has as its object to provide a process of production of a permanent magnet excited synchronous machine, and a rotor produced by this process, according to which the permanent magnets are mounted hydrostatically, so to speak, and furthermore the permanent magnets also have no unprotected surfaces even after sustaining fractures after first running up to operating speed.

[0005] The process according to the invention is distinguished in that the core is constituted with an internal space, and a resin mass is introduced into the internal space and is supplied to the region of the permanent magnets by centrifuging the rotor, a hardening of the resin mass then taking part in the said region. The rotor produced by the process according to the invention is characterized by a core of ferromagnetic steel and an internal space extending axially, the permanent magnets being arranged on the said core and being surrounded by an outer cylinder of non-magnetizable material, the said rotor having closure disks of non-magnetizable steel at both ends with stub shafts, which are positively connected to the core and at least frictionally connected to the outer cylinder, and that all the cavities in the region of the permanent magnets are filled with a resin mass.

[0006] The advantages attained with the invention are in particular that the permanent magnets are completely surrounded by the resin mass and thus in actual fact are hydrostatically mounted, so that they are secured against a displacement due to centrifugal forces; and that the resin mass is still flowable during the first running-up to speed, so that it fills the cracked regions of the permanent magnets appearing during this period, and covers the additionally resulting bare surfaces of the permanent magnets.

BRIEF DESCRIPTION OF THE DRAWING

[0007] Preferred embodiments of the invention are discussed in the following description and illustrated in the accompanying drawings, in which:

[0008] Fig. 1 shows a longitudinal section through a first embodiment of the rotor according to the invention.

[0009] Fig. 2 shows a section along the line II-II of Fig. 1.

[0010] Fig. 3 shows a first embodiment of the connection between the outer cylinder and a closure disk of the rotor.

[0011] Fig. 4 shows a second embodiment of the connection between the outer cylinder and a closure disk of the rotor.

[0012] Fig. 5 shows a third embodiment of the connection between the outer cylinder and a closure disk of the rotor.

[0013] Fig. 6 shows, on an enlarged scale, a cross section through a portion of the rotor, in order to illustrate the filler strips.

[0014] Fig. 7 shows a longitudinal section, similar to that of Fig. 1, through a portion of a second embodiment of the rotor according to the invention.

[0015] Fig. 8 shows a diagram of a slotted sheet of a sheet metal packet shown in Fig. 7.

[0016] Fig. 9 shows a schematic view of a portion of a rotor with a cage.

[0017] Fig. 10 shows a section along the line X-X of Fig. 9.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The rotor of the first embodiment, shown in Fig. 1, has an integrally constituted core 1 of a ferromagnetic material. Permanent magnets 2 are arranged on the core 1. The permanent magnets are shown as one piece for the sake of clarity, but they can however also be arbitrarily divided. The permanent magnets 2 are surrounded by an outer cylinder 3 of a metallic, non-magnetizable material. The outer cylinder 3 can consist, for example, of high strength, cold-rolled, austenitic steel, or of a high strength bronze which conducts electricity well, e.g., CuNi₃Si, to achieve the smallest electrical surface losses. The rotor ends on both sides with a closure disk 4 or 5 with a stub shaft 6 or 7 which consists of non-magnetizable steel.

[0019] The core 1 has an internal space 8 constituted as an axial through bore, which serves as a storage space as will be described. Channels 27 run in a radial direction from the internal space 8 to the region of the permanent magnets 2.

[0020] The core 1 furthermore has a polygonal recess 18 at both axial ends. The closure disks 4 or 5 have a correspondingly shaped projection 19. The core 1 is centered on the closure disks 4 or 5 by means of these projections 19 and recesses 18, the polygonal shape moreover serving for excellent transmission of the torque of the core 1 to the closure disks 4 or 5 and thus to the stub shafts 6 or 7. Instead of a central projection 19, there can be an arrangement of shear bolts 38 which connect the core 1 to the closure disks 4 or 5.

[0021] Fig. 2 shows a section through the rotor along the line II-II of Fig. 1. It can be seen that the permanent magnets 2 seated on the core 1 are encircled by the outer cylinder 3, and the core 1 has the internal space 8. In a known manner, the rotor forms a north pole N and a south pole S in the 2-pole embodiment shown here by way of example. Lateral, magnetically neutral zones 37 are present, as is generally known. Filler pieces 16 of a magnetizable or non-magnetizable material, according to the desired magnetic salience, are inserted at these neutral zones 37, in the corresponding annular space portions between the outer cylinder 3 and the core 1. The density of the material of these filler pieces 16 is advantageously at least approximately equal to the density of the material of the permanent magnets 2, that is, the density of the filler pieces 16 is advantageously similar to the density of the permanent magnets 2.

[0022] For the assembly of the rotor, the outer cylinder 3, according to a variant, is shrunk onto the closure disks 4 or 5.

[0023] The final connection between the outer cylinder 3 and the closure disks 4 or 5 takes place according to a first embodiment, which is shown in Fig. 3, by means of a tight peripheral weld seam 9. As will be described hereinafter, the production of this tight peripheral weld seam 9 takes place in two steps.

[0024] A further embodiment of the connection between the shrunk-on outer cylinder 3 and the closure disks is shown in Fig. 4.

[0025] The outer cylinder 3 of this embodiment has at both ends an inner circumferential groove 10. The respective closure disk 4 or 5 has a corresponding outer circumferential projection 11. Near this outer circumferential projection 11 is an outer circumferential groove 12 with an O-ring 13 inserted into it. If the outer cylinder 3 is shrunk onto the respective closure disk 4 or 5, the respective outer circumferential projection 11 projects

into the respective inner circumferential groove 10. Furthermore, the respective O-ring 13 directly abuts the outer cylinder 3.

[0026] Fig. 5 shows a further variant of the connection between the outer cylinder 3 and the closure disk 4 or 5, in which no shrinking-on takes place. The respective closure disk 4 or 5 has for this purpose a cone-shaped portion 14 facing toward the rotor interior. This cone-shaped portion 14 ends in a shoulder portion 15 formed as a stop. In this embodiment, the closure disks 4, 5 are hydraulically pressed in over the cone-shaped portion 14 until they come to abut on the shoulder portion 15 in the outer cylinder 3.

[0027] Reference is made to Fig. 6 in addition to Fig. 5. The core 1 shown in Fig. 6 has a polygonal circumferential surface. The dimensions of the flat-surfaced surface portions 17 of the outer circumference of the core 1 correspond to the dimensions of the permanent magnets 2 arranged on it. Thus the circumferential surface of the core 1 conforms to the contour of the permanent magnets 2, so that no large magnetic gap is present. Furthermore, excellent transmission of torque from the permanent magnets 2 to the core 1 results from this polygonal shaping of the circumferential surface of the core.

[0028] Filler strips 20 of a dimensionally stable, preferably metallic, material are arranged between the individual permanent magnets 2. These filler strips can be provided with a thin nonwoven covering for fitting purposes, at least opposite the permanent magnets. Further filler strips 21 are arranged between the permanent magnets 2 and the opposing inner circumferential regions of the outer cylinder 3. These further filler strips 21 consist of material which conducts well, e.g., Cu or Al.

[0029] Excellent fitting to the rectangular cross sectional shape of the permanent magnets 2 is made possible by the filler strips 20, 21. If absolutely necessary, only the faces of the permanent magnets 2 facing the outer cylinder 3 are ground; for the rest, all the surfaces can remain unworked.

[0030] The further filler strips 21 are connected at their ends to a flexibly constituted ring 22 which conducts electricity well; see also Fig. 5. This ring 22 can consist of a braided wire or can be of laminated construction. The connection of the further filler strips 21 to the flexible ring 22 can take place by welding, e.g., spot welding.

[0031] These further filler strips 21 together with the ring 22 thus form a damping cage. During assembly of the rotor, these weld connections are produced before the positioning and securing of the closure disks 4, 5 on the outer cylinder 3.

[0032] In the embodiment shown in Fig. 7, the core, generally denoted by the reference numeral 35, is embodied of stacked metal sheets 23. These metal sheets 23 are arranged as a metal sheet packet on a centering tube 24. The centering tube 24 has holes 25 running in a radial direction. The metal sheets 23 arranged in the neighborhood of these holes 25 have a longitudinal slot 26 and are stacked in a cyclically rotated arrangement (see Fig. 8), so that passages from an internal space 36 of the centering tube 24 to the region of the permanent magnets 2 are present, analogous to the channels 27 of the first embodiment.

[0033] Instead of the centering tube 24, the metal sheets 23 can be perforated in order to be able to receive shear bolts 38. These shear bolts 38 can project in over the length of the metal sheet packet and into the closure disks 4, 5, in order to transmit torque.

[0034] The embodiment with a core 35 of a metal sheet packet is a precondition for an oscillating magnetization. However, this embodiment has no damping cage according to that of the embodiment shown in Figs. 5 and 6.

[0035] The reference numeral 28 in Fig. 7 denotes, in each closure disk, periodically annularly positioned threaded holes to receive balancing screws (not shown) for balancing the rotor. Alternatively, bores with desired diameter and depth can be bored during balancing.

[0036] A yet further embodiment is shown in Figs. 9 and 10. A cage 29 with end rings 30 and longitudinal rods 31 is produced from a material (e.g., Cu, Al) which conducts well, and acts as an electrical damping cage in the finished rotor. To assemble the rotor, this cage 29 is pushed into the outer cylinder 3. The individual permanent magnets 2 are inserted into the cage 29, which serves as a filling matrix, and are adhered to the outer cylinder with a provisional adhesive. Thereupon the core 1 is pushed into the cage 29, and the closure disks 4, 5 are then mounted.

[0037] Alternatively, the cage 29 with the permanent magnets 2 can first be arranged on the core 1 and then the outer cylinder 3 can be pushed over them.

[0038] The purpose of the transverse grooves 32 in the longitudinal rods 31 will be explained hereinafter.

[0039] To complete the rotor according to the invention, a resin mass is introduced into the internal space 8, serving as a storage space, of the core 1, or in the embodiment according to Fig. 7, into the internal space 36 of the centering tube 24. Such resin masses are generally known and thus do not have to be described further. These resin masses can furthermore contain fillers, e.g., an aluminum oxide powder. Advantageously, the resin mass is introduced in the form of a solid rod, as a so-called B-stage adhesive.

[0040] The rotor is then run up to speed and simultaneously heated, according to a predetermined time program. The program can include steady state points at intermediate rotational speeds and intermediate temperatures. The resin mass, now molten, thus penetrates through the channels 27 in the core 1 or, in the embodiment of Fig. 7, through the holes 25 in the centering tube 24 and through the longitudinal slots 26 in the relevant metal sheets 23, in a radially outward direction toward the permanent magnets 2. The transverse grooves 32 described in Fig. 9 serve to equalize the flow of the resin mass.

[0041] The resin mass flowing outward due to the centrifugal force fills all the cavities present, and the permanent magnets 2 are completely surrounded by the resin mass. Since it is known that cracks and fractures unavoidably occur in the brittle permanent magnets when the rotor is first run up to speed, these regions also are reliably filled by the flowable resin mass.

[0042] The hardening of the resin mass takes place at the centrifuging speed of the rotor. This speed is higher than the maximum rotational speed and is only applied during manufacture of the rotor.

[0043] The region of the inner level of the resin mass after centrifuging is shown in Fig. 1 by the arrows 33 and 34 and also by the dashed lines. The resin mass to be filed into the internal space is thereby determined.

[0044] Due to the hardening of the resin mass during centrifuging, the outer cylinder 3 remains prestressed at the later rotational speeds and when stationary.

[0045] It is to be mentioned that the peripheral weld seam 9 described in connection with Fig. 3 is pre-welded only in a single pass before the described course of hardening. The

circumferential weld seam 9 is completely after-welded only after the course of hardening. The outer cylinder 3 is seated on cooled clamp jaws (not shown) during the welding process. The balancing of the rotor takes place at the threaded holes 28, described in Fig. 7, after the course of hardening. The internal space 8 in the core 1, or the internal space 36 of the centering tube 25, can furthermore serve as a so-called heat pipe and be cooled via the stub shafts 6, 7 or by means of flanged-on heat exchangers. It is within the scope of the present invention that the rotor has a stub shaft at only one side, and the other end remains free. The closure disk at the free end remains for sealing purposes.

[0046] It is thus apparent that the permanent magnets are mounted hydrostatically, so to speak, and in particular that cracks occurring when the rotor is first run up to speed are filled with the molten resin mass, so that the permanent magnets are completely locked in from the ambient atmosphere and thus are extremely corrosion-resistant.

[0047] The permanent magnets can be provided with insulating coatings in order to prevent current paths to adjacent electrically conducting components.

[0048] As an alternative mode of manufacture, prestressed flat binding strips can be placed around the permanent magnets and possible damper rods 21 before the installation of the outer cylinder 3. The permanent magnets can then be magnetized in an oscillating manner. The rings 22 are thereafter applied, without however removing the strips. Alternatively, the filler strips 20 can likewise consist of material which conducts electricity well, and can be connected to the rings 22.